and compositions, do affect profoundly their economic uses. The results of the present research emphasise the importance of the chemical composition of a combustible gas (or mixture) as a factor which cannot be disregarded when its economic value is in question.

Further experiments at high pressures are in contemplation to develop the matters dealt with in this paper; and it is intended also to make similar experiments at atmospheric pressure.

Our thanks are due (*a*) to the Government Grant Committee of the Society for grants out of which the cost of the expensive apparatus employed in the research has been defrayed, and (*b*) to the Salters' Institute of Industrial Chemistry for the Fellowship granted to one of us (W. A. H.) to enable him to devote his whole time to the work.

On the Spectra of Lead Isotopes.

By T. R. Merton, F.R.S.

(Received July 12, 1921.)

In a previous communication* an account was given of comparative measurements of the wave-length of the line $\lambda = 4058$ Å. in the spectra of ordinary lead and of the leads obtained from uranium and thorium minerals respectively. The line $\lambda = 4058$ Å. is the strongest line in the arc spectrum of lead and the results obtained were

$$\lambda \text{ (lead from pitchblende)} - \lambda \text{ (ordinary lead} = 0{\cdot}0050 \pm 0{\cdot}0007 \text{ Å.}$$

$$\lambda \text{ (ordinary lead)} - \lambda \text{ (lead from thorite)} = 0{\cdot}0022 \pm 0{\cdot}0008 \text{ Å.}$$

The lead from pitchblende had been extracted from some Joachimstal pitchblende residues, and since this mineral is known to be free from thorium there was no reason to suspect that the sample of lead obtained was contaminated with lead of a thorium parentage. It was not known whether any ordinary lead was present but the wave-length difference which was found agreed closely with the value found by Aronberg* in a comparison of the same spectrum line of ordinary lead and a sample of lead from Australian Carnotite for which Prof. Richards had found an atomic weight of 206·318.

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* 'Roy. Soc. Proc.,' A, vol. 96, p. 388 (1920).

† 'Astrophys. Journ.,' vol. 27, p. 96 (1918).

The thorium lead had been given to me through the kindness of Prof. Soddy and had been extracted from the mineral thorite, and it was known to be not entirely free from contamination by lead of a uranium parentage, since thorite contains a small proportion of this element.

It is a matter of some interest to discover whether this wave-length difference, or the corresponding wave-number difference, is to be found between all corresponding lines in the spectra of the isotopes; whether the spectrum lines are shifted as a whole or whether different lines are affected to a different extent or in a different direction. Very little remained of the samples which had been used in the previous investigation, but I have recently received, through the kindness of Mr. Lambert, a relatively large quantity of a sample of lead from Australian Carnotite, and it was accordingly decided to compare a number of lines in the spectrum of this sample with the lines in ordinary lead.

The method of measurement and reduction has been described fully in the previous investigation (*loc. cit.*). In the present measurements a Hilger quartz spectrograph was used to separate the fringe systems produced by the étalon in place of the glass spectrograph which was used previously, owing to the absorption of the more refrangible radiations by the glass prism. It has been pointed out (*loc. cit.*) that certain experimental errors can be avoided by using as a source an electric arc burning *in vacuo* with a pole consisting of an alloy of the sample of lead under investigation and cadmium, the wave-lengths being thus determined on each plate in terms of a selected cadmium line, but it has been found that the plates which were most suitable for the comparison of the lead line $\lambda = 4058$ Å. with the cadmium line $\lambda = 4800$ Å. were not so well adapted for the comparison of the more refrangible lead lines, and it has therefore been found more convenient to carry out the measurements in two parts, that is to say a comparison of the line $\lambda = 4058$ Å. from the Carnotite lead and from ordinary lead with a cadmium line, and a comparison of the different lines with one another in each sample of lead.

The only objection to this procedure appears to be that in so far as the absolute values of the differences in the two spectra are concerned the probable error in the difference found for $\lambda = 4058$ Å. must be added to the probable errors for each of the more refrangible lines, but this consideration does not apply to the relative shifts found for the different lines. It may be recalled that since the differences in wave-length are small it is only necessary to determine the fractional values (f) of the orders at the centres of the ring systems and to reduce these to the same standard of $f=0$ for the standard line. Two series of three plates each for each sample of lead, gave the following results, the cadmium line $\lambda = 4800$ Å. being used as standard. The difference in wave-length corresponding to a shift of a whole order is equal to $\lambda^2/2d$, where λ is the wave-length of the line and d the thickness of the étalon, which in these experiments was 9·80 mm.

Values of f (reduced to $f = 0$ for cadmium $\lambda = 4800$ Å.).

	Ordinary lead.	Lead from Carnotite.
	0·293	0·171
	0·292	0·158
	0·294	0·180
	0·277	0·191
	0·275	0·158
	0·294	0·160
Mean =	0·287 ± 0·004	0·170 ± 0·006

Difference = 0·117 ± 0·010.

λ (lead from Carnotite) − λ (ordinary lead) = 0·0098 ± 0·00084 Å.

A further set of three pairs was taken on plates on which the cadmium standard $\lambda = 4800$ Å. was not recorded and in reducing these plates the cadmium line $\lambda = 3404$ Å. was used as a standard, though the fringes obtained with this line were not quite so well defined as in the case of $\lambda = 4800$ Å. The results were as follows:—

Values of f (reduced to $f = 0$ for cadmium $\lambda = 3404$ Å.).

	Ordinary lead.	Lead from Carnotite.
	0·725	0·557
	0·700	0·559
	0·692	0·563
Mean =	0·706 ± 0·010	0·560 ± 0·002

Difference = 0·146 ± 0·012.

λ (lead from Carnotite) − λ (ordinary lead) = 0·012 ± 0·001 Å.

From these results it is believed that a value for the difference in wave-length of 0·011 ± 0·0008 Å. may be adopted. This value is of the same sign but rather more than twice as great as that obtained in the previous investigation in which ordinary lead and lead from pitchblende residues were compared. The most probable explanation of this difference is evidently that the Carnotite lead used is a purer sample of uranium lead than that obtained from the pitchblende residues. There remained the very remote possibility of some difference between the "ordinary" leads used, a sample from Kahlbaum having been used in the former measurements, whilst a sample of assay lead from Messrs. Johnson and Matthey was used in the experiments recorded above. As a sample of the Kahlbaum lead was still available, three pairs of plates were taken to compare the wave-length of the line λ = 4058 Å. in these two samples, but the discrepancy between the values obtained amounted to only one thousandth of an Ångström: a difference which is too small to be considered as having any real significance.

A number of attempts have been made to observe the line λ = 4058 Å. as a close double in the spectrum of an alloy of the two leads, using a 35 plate échelon with plates 15 mm. thick. The observation should be just within the resolving power of the instrument, but it was not possible to obtain any positive results owing to the widths of the lines. Four other lines λλ = 3740, 3684, 3640, and 3573 Å. have been compared with λ = 4058 Å. in the spectra of the Carnotite and ordinary lead, these being the only lines which were bright enough for investigation with the apparatus at present available. Three pairs of plates have been measured; the details are not given, being similar to those given above for the line λ = 4058 Å., but the final results are set forth in the following table:—

λ	λ (Carnotite lead) − λ (ordinary lead).	Wave-number (ordinary lead) − Wave-number (Carnotite lead).
4058	0·011 ± 0·0008 Å.	0·065 ± 0·005
3740	0·0074 ± 0·0011 Å.	0·053 ± 0·008
3684	0·0048 ± 0·0007 Å.	0·035 ± 0·005
3640	0·0070 ± 0·0003 Å.	0·052 ± 0·002
3573	0·0048 ± 0·0005 Å.	0·037 ± 0·004

It has already been pointed out that in so far as absolute values of the differences are concerned, the error for λ = 4058 Å. should be added to those for the other lines. It is apparent that the differences are not the same for the different lines though they appear to be almost identical for the lines λλ 3740 Å and 3640 Å., and for λλ 3684 Å. and 3573 Å. This result is somewhat surprising, for although little is known of the series relations in the spectrum of lead, the lines λλ 3740 Å and 3573 Å. are members of a group which is related to other groups in the spectrum by constant differences in wave-number, and a similar behaviour might therefore have been expected in these lines; but the apparent agreement in the displacements of the two pairs of lines may be partly accidental. The difference in the line λ = 4058 Å. in the two isotopes is about two hundred times as great as would be expected on Bohr's theory, if the difference is calculated in the same manner as the difference between the Balmer lines of hydrogen and the enhanced helium lines; but as the theory has not yet been extended successfully to the arc lines of the heavier elements, the comparison is of no great value.

I should like to express my indebtedness to Mr. S. Barratt for his help in making the measurements, and to Mr. Fensom for his skilful assistance.

The Adsorption of Gas by Charcoal, Silica, and other Substances.

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(Communicated by Prof. J. F. Thorpe, F.R.S. Received March 9, 1921.)

1. *Introduction.*

The experimental work here described was carried out on behalf of the Oxygen Research Committee and the Mine Rescue Apparatus Research Committee of the Scientific and Industrial Research Department. The main object of the experiments was to investigate the possibility of obtaining a non-inflammable substitute for the activated charcoal used in metal vacuum flasks intended for holding liquid air. The work was eventually extended so as to include an examination into some of the more theoretical aspects of gas adsorption.

The special problems presented by the metal vacuum vessel made it necessary to pay particular attention to the adsorption of nitrogen at liquid air temperature. Many measurements have also been made using hydrogen.

2. *Preparation of Non-inflammable Adsorbents; their Capacity at Liquid Air Temperature.*

A large number of non-inflammable substances were prepared and were tested to ascertain their capacity for nitrogen at the temperature of boiling liquid air and at normal pressure. The liquid air used had an average composition of 50 per cent. oxygen and 50 per cent. nitrogen; this mixture boils at −190° C. The materials, which were in the granular state, were tested in a uniform manner. Immediately before being used, each sample was heated in a gas-oven for several hours at a temperature of 300° C. The sample was inserted, while hot, into a hot brass retort, holding 25 c.c., and well shaken down. A cap, having a copper tube brazed into it, was screwed